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Therapeutic Effectiveness of Postural Treatment on Youth Swimmers' Anterior Shoulder Pain—An Interventional Study

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Abstract: The aim of our study was to investigate the effects of a 24-week-long training program on changes in static body posture, as well as the characteristics of anterior shoulder pain in youth swimmers, and the relationship between changes in whole-body posture and the frequency and intensity of anterior shoulder pain. Competitive young swimmers (n = 54, 13.9 ± 1.79 years) were divided into experimental group and control group and both groups performed their usual swimming training. In addition, the experimental group performed a 24-week-long whole-body posture correction program. Before and after the implemented training, whole-body posture was analyzed using the PostureScreen (version 13.7) mobile application, and subjective intensity of pain was determined using the swimmer's functional pain scale. Significant changes were found between the two groups in numerous measured postural parameters. A significant reduction in the prevalence of shoulder pain and score of the pain scale was observed after the posture correction program in the experimental group. Our results may imply that more optimal biomechanical conditions may indirectly reduce the incidence of swimmer's shoulder in terms of prevention. Analysis and monitoring of body posture of swimmers using an on-field mobile application continuously, and the application of preventive training programs, may help to avoid developing injuries.

Keywords: swimming; posture correction; shoulder pain; mobile application; youth

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1. Introduction

A chronic musculoskeletal complaint common to swimming is pain in the anterior shoulder [1]. This symptom is often referred to as "swimmer's shoulder", which describes anterior shoulder pain caused by dysfunction, but does not define a specific clinical diagnosis [2] (. According to the current literature, the prevalence of this phenomenon is very high in adult [3–6] and young [2,7,8] competitive swimmers, ranging from 35% to 91% depending on age, gender, and training volume, and the first painful event may occur as early as 11 to 13 years of age [7]. Although highly repetitive overhead strokes (e.g., freestyle swimming, [9], up to 2500/day and 16,000/week, are the primary cause [6,10], shoulder mobility, force imbalances, and static or dynamic postural abnormalities [4–6,11–15] could also contribute to pain.

Common postural abnormalities in swimmers take the form of the more typical "swimmer's posture", described as a forward leaning head posture, increased thoracic kyphosis and protracted shoulder girdle [14,16,17] Good posture refers to the natural and balanced maintenance of various parts of the body [18] Its importance in sport is that athletes with poor posture are exposed to a greater risk of injury due to altered joint positions and established muscle imbalance. Poor posture can cause imbalance between agonist and antagonist muscles', and decreased range of motion in spinal joints, which could be associated with the development and persistence of shoulder pain [14,16,19]. The first pain event could occur as early as adolescence [7], an age period characterized by rapid growth and being prone to poor posture. Furthermore, the risk of injury is higher in adolescent swimmers with increased training volume [20] . Therefore, the focus should be on the overall posture and attention should be paid to the assessment of overall posture with a validated method to find out how the misalignment of a distal segment could lead to development of a painful shoulder.

Posture testing for competitive swimmers is limited to the upper body. Different methods (double-square method, photogrammetric analysis, inclinometer) were used for analyzing the posture. According to Saggini and Barassi's recommendations [21,22], these methods can be used to objectively determine the rate of incorrect posture for each body part or the whole-body posture using photogrammetry, Botha et al. described significant differences between female adolescent freestyle swimmers and non-swimmers for all variables of upper-quarter posture [23]. Head tilt angle, cervical angle, and shoulder protraction–retraction angles were smaller and thoracic angle was larger in the swimmers' group. Incorrect posture and abnormalities can be corrected and pain can be reduced by targeted training intervention [2,24].

A novel method for analyzing whole posture is the use of the PostureScreen mobile application [25]. In one study [26] , the app was used to assess the changes in whole posture after a stabilization exercise and stretching intervention in adult swimmers. Tracking exercise-induced changes in whole-body posture using the PostureScreen application could be a novel approach in both injury management and prevention, but whether it contributes to shoulder pain reduction is unclear.

Several publications [2,3,16,17,24,27–31] highlighted that dry-land training could have a beneficial effect on the restoration of normal shoulder posture and muscle balance in competitive swimmers, but less information is available on whether pain is reduced, if at all, and most of these studies have selectively treated shoulder muscles. For swimmers the results of earlier publications [2,3,16,17,24,29–32] suggested that preventive interventions to improve postural change applied core training combined with shoulder strengthening and stretching exercises may improve posture and decrease the presence of shoulder pain. These previous studies highlight the importance of core strengthening in the prevention of shoulder pain as a way to create/build the proximal stability necessary for the optimal biomechanical function of the upper limbs. There is still no evidence that full postural correction training reduces shoulder pain. Young athletes, because they are trained during their growth period, may be even more susceptive to these treatments than adults.

In the current study, therefore, we applied the previously validated PostureScreen mobile application to monitor whole-body changes induced by a 24-week-long whole-body posture correction (WBPC) exercise routine, and its impact on the pain status of youth competitive swimmers.

The present study provides evidence that swimmers' shoulder pain reduction can be targeted by whole-body posture correction, i.e., exercising all the body segments distal from the shoulder joints itself.

The aim of our study was to investigate the effects of 24 weeks of the WBPC program on changes in whole-body posture in youth swimmers. A further aim of the current study was to look for the correlation between variables of the posture analysis and the shoulder function-related pain.

2. Methods

2.1. Participants

Competitive swimmers (n = 54; aged 12 to 18 years) were recruited from a local swimming club for competitive swimmers at national level during the competition season. Athletes were randomly divided into experimental (EXP) and control groups (CON). As our specific postural correction exercise protocol was designed both for pain development prevention and treatment, swimmers both with and without anterior shoulder pain were recruited. All participants had been attending swimming training for at least four years and had at least four training sessions per week (average swimming training time: 12.63 ± 3.47 h/week). Exclusion criteria were an unsigned consent form, acute injuries, and surgery in the last 6 months. No athletes were excluded.

Before each measurement, participants and their parents received detailed written and verbal information about the program. They then signed an informed consent form to participate in the study. The study was conducted in accordance with the Helsinki Declaration, and the protocol was approved by the Regional and Institutional Committee of Science and Research Ethics (permit number: 6154-PTE 2019).

2.2. Design and Procedures

The CON group continued their regular training routine during the intervention period. The EXP group performed whole-body posture correction dryland training (WBPC) for 30 min, three times a week for 24 weeks in addition to regular swimming training.

During the study period, two (pre-WBPC and post-WBPC) measurements were taken to determine static standing posture using the PostureScreen mobile application according to Boland's method [23], and the presence of anterior shoulder pain using the swimmer's functional pain scale (SFPS). The participants also completed a self-administered questionnaire about their training history. They described their usual training frequency and duration, and years of swimming training.

The International Society for Advancement of Kinanthropometry method was followed for all anthropometric measurements which were performed by the same investigator consistently using the same devices. Body height (Seca 210 stadiometer, Seca Corporation, Hamburg, Germany) and body mass (Omron BF-511, Kyoto, Japan) of the participants were measured, and body mass index (BMI) was calculated.

An orthopedic specialist physically examined the swimmers' shoulder, and he paid close attention to shoulder positioning at rest and symmetry in motion to assess for abnormal motion or a possible strength deficit.

The swimmers' static standing posture were analyzed using the PostureScreen mobile app to provide information on the translation and angulation of body parts in sagittal and frontal planes. With this method, we were able to quantify the postural variation caused by the intervention for each participant.

3. Measures

3.1. Standing Posture Analysis

All measurements were taken before the afternoon training sessions (16:00–18:00) at a constant temperature of 22 °C in the examination room. It was a requirement that no food or drink was consumed 2 h before assessment. Photogrammetric posture analysis is a common method of postural analysis and therefore images of the swimmers' habitual posture were taken from 2 (frontal and lateral) sides. According to Boland's (2016) [33] study, the subject was positioned 50 cm from a homogeneous background, and a mobile device used for photography was positioned 3 m from this line and 1.37 m above ground. When a photo was taken in both aspects, subjects were required to be barefoot. Girls wore swimsuits and boys wore swimming pants. Girls with long hair were asked to tie their hair up so that their neck and shoulders were exposed. To test the habitual posture test, we asked for the usual spontaneous posture to be taken; no other posture instructions were given.

Photos were analyzed using the PostureScreen mobile (PSM) application (PostureCo, Inc., Trinity, FL, USA) [25,34]. The PSM calculates posture variables using digitized anatomical landmarks. The following landmarks are in lateral view: external auditory meatus, shoulder center at cervicothoracic junction, cervical 7th vertebra, thoracal 12th vertebra, greater trochanter, tibiofemoral joint center, and center of the malleolus. The following landmarks are in anterior view: center of eyes, sternal notch, bilateral acromioclavicular joints, bilateral T8 ribs bilateral anterior superior iliac spines, and center of bilateral anterior ankles.

Posture was described by PSM-related algorithms using the following variables which we monitored before and after the WBPC program (angulations are measured in degrees, translations are measured by centimeters).

1. Angulation of thoracic kyphosis (ATK): the convex curvature of the dorsal spine and normally is between 20 to 40 degrees [35]. It is also calculated by anatomical landmarks using the PSM algorithm.
2. Cervicovertebral angulation (CVA): the angle formed by a horizontal line drawn through the seventh cervical (C7) vertebra and a line joining the C7 vertebra to the tragus of the ear. A smaller CVA indicates a greater forwards head posture. A CVA less than 48–50 is defined as forward head posture [36].
3. Angulation of skull flexion (ASF): defined as the angle between the horizontal line drawn across the tragus and the line drawn from the corner of the eye to the tragus.
4. Total anterior angulation (TAA): the total angulated deviations of different body parts in anterior view.
5. Total lateral angulation (TLA): the total angulated deviations of different body parts in lateral view.
6. Total anterior translation (TAT): the total translated deviation of different body parts in anterior view.
7. Total lateral translation (TLT): is the total translated deviation of different body parts in lateral view.

The term "total" parameters refers to the extent of deviations observed in each body part, and these deviations are consistently calculated in relation to the inferior segment. The calculation methods for the lateral view can be found in Figure 1.

3.2. The Swimmer's Functional Pain Scale

The swimmer's functional pain scale (SFPS) is a questionnaire for swimmers to assess existing and subjective levels of pain related to shoulder function-related pain. It has been shown to help identify current health problems in the shoulder area [37] . The aim of the SFPS questionnaire is to provide a self-reported assessment that shows shoulder pain and the possible need of further examination objectively.

3.3. Whole-Body Postural Correction (WBPC) Training

Our WBPC program was designed based on previous interventions for swimmers [6,9,11,17,37,38]. The focus was on improving whole-body posture with strengthening and stretching exercises on the trunk and shoulders. Our WBPC program lasted 24 weeks (with three 8 weeks long periods), and sessions were carried out three times a week for 30 min on land. The program was suitable for both those with pain at both the primary and secondary level of prevention, and for those without pain. Details of three training sessions over the 24-week-period are shown in Table 1. The load progressively increased from period 1 to 2, and from period 2 to 3.

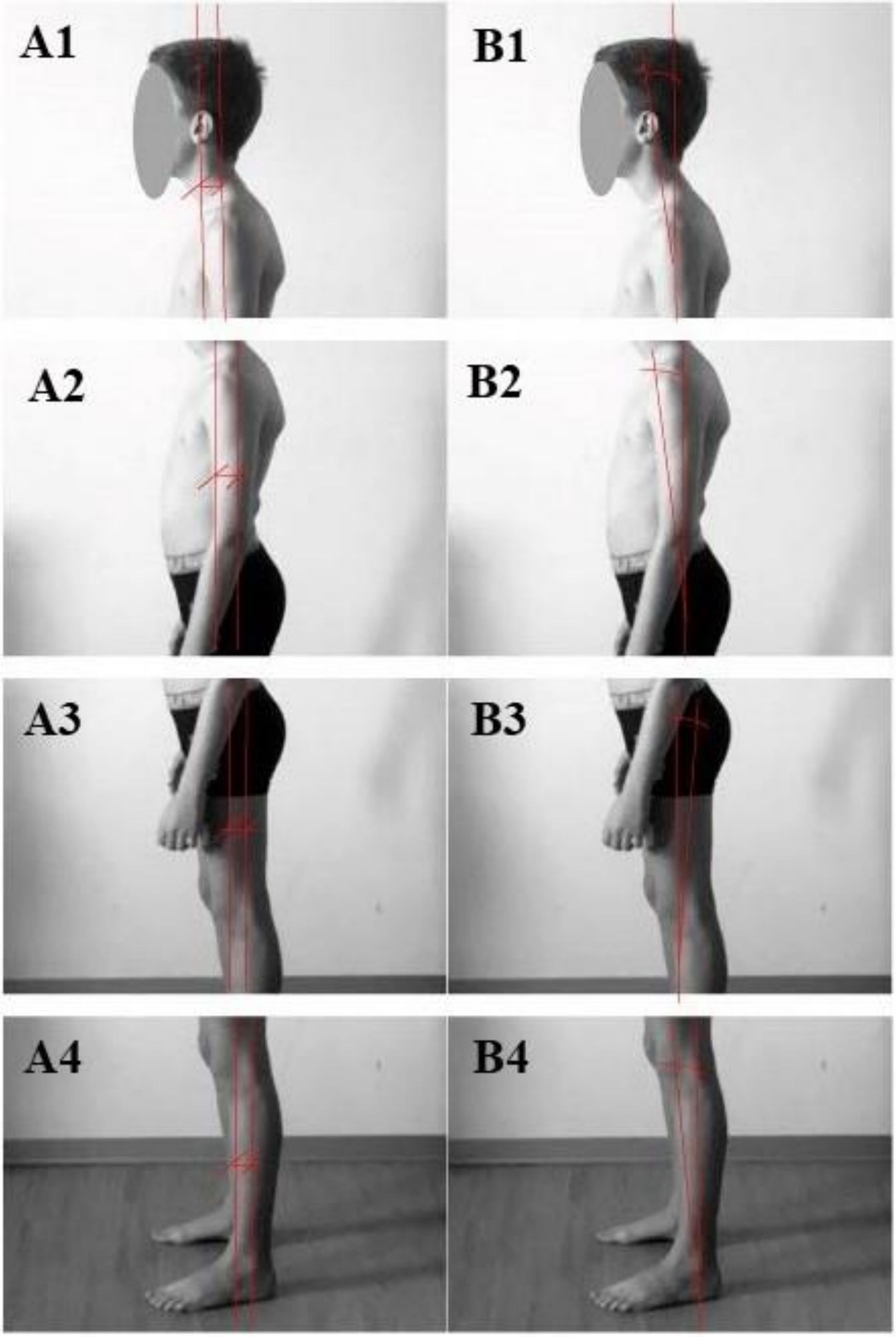

Figure 1. Sample of translations and angulations as calculated by the PostureScreen mobile application. Abbreviations: (**A1**) calculation of head translation, (**A2**) calculation of shoulder translation, (**A3**) calculation of hip translation, (**A4**) calculation of knee translation, (**B1**) calculation of head angulation, (**B2**) calculation of shoulder angulation, (**B3**) calculation of hip angulation, and (**B4**) calculation of knee angulation.

Table 1. Description and progression of WBPC training program.

	1st Session	2nd Session	3rd Session
Training period (week)	8	8	8
Training frequency (times/week)	3	3	3
Training duration (min/day)	30	30	30
Content of intervention training	1a: core strengthening: abdominal, paravertebral and gluteal exercises	1a: same as 1st session	1a: core strengthening:abdominal, paravertebral and gluteal exercises with fitball
	1b: shoulder strengthening: scapular retraction and depression exercises and complex shoulder workout (m.trap.med and inf., m.serratus ant., mm.rhomboidei, m.delt., mm.rotator cuff)	1b: same exercises with resistance band	1b: same as 2nd session
	2: core stability exercises	2: core stability exercises with movements of extremities and trunk	2: core stability exercises with fitball
	3: stretching exercises m.trap.sup., m.lat.dorsi, mm.pect	3: same as 1st session	3: same as 1st session
Sets/reps or Set/duration	1a–1b: 3/20 2: 5/30 s 3: 3/30 s	1a–1b: 3/20 2: 5/30 s 3: 3/30 s	1a–1b: 3/20 2: 5/30 s 3: 3/30 s
Rest between sets (s)	30	30	30

Abbreviations: m.trap.med. and inf.: pars medius and inferior of trapezius muscle, mm.rhomboidei: rhomboideus muscles, m.delt: deltoideus muscle, mm.rotator cuff: muscles of rotator cuff, m.trap.sup.: pars superior of trapezius muscle, m.lat.dorsi: latissimus dorsi muscle, mm.pect: pectoralis muscles.

4. Statistical Analyses

For the measured parameters, descriptive statistics (mean, standard deviation, and frequency) were defined. The Kolmogorov–Smirnov test was performed to test normality, and the Mann–Whitney and independent sample t-test were performed to detect significant differences between the EXP group and the CON group.

A two-way mixed-effects consistency model was used for the inter-test reliability analysis of the PostureScreen data. The pre-interaction coefficients (preICC) of the PostureScreen variables were between 0.65 and 0.98, and post-interaction coefficients (postICC) ranged from 0.88 to −0.99.

To qualify the effect sizes Cohen's d values were calculated based on the significantly changed variables and d values were interpreted based on Cohen (1988) [39].

The calculated changes of variables were calculated between pre- and post-WBPC variables. The Pearson correlation test was applied to investigate the relationship between change of PostureScreen data and change of SFPS score. We used IBM SPSS 28.0 statistical software. Significance level was $p < 0.05$.

5. Results

5.1. Anthropometric Characteristics and Swim Training Load of the Participants

A total of 54 participants were divided into intervention (EXP $n = 32$) and control (CON $n = 22$) groups. Before the intervention training program, there were no significant differences between two groups considering anthropometric parameters and swim training characteristics on the results of the independent sample t test (Table 2).

Table 2. Anthropometric parameters and training characteristics of participants.

	EXP (n = 32)		CON (n = 22)		
	Mean	**SD**	**Mean**	**SD**	***p* Value**
Age (years)	13.80	1.89	14.04	1.67	0.636
Height (cm)	169.18	8.77	166.07	9.42	0.227
Weight (kg)	56.93	11.62	56.54	11.58	0.902
BMI (kg/m^2)	19.72	2.60	20.27	2.54	0.446
Years of swimming	6.93	1.79	7.04	2.05	0.843
Training duration (min/day)	105.00	15.24	103.63	15.28	0.749

Abbreviations: BMI: body mass index, EXP: experimental group: CON: control group, SD: standard deviation, *p*: level of significance.

5.2. Results of the Swimmers Functional Pain Scale (SFPS)

There were 40 swimmers who had shoulder pain in the beginning. Twenty-three of them were in the experimental group and seventeen were control subjects. No significant difference in shoulder pain frequency and intensity was found between the two groups before the WBPC program (Figure 2). After the WBPC program, a significant change in shoulder pain frequency was observed in the swimmers participating in the WBPC program (Figure 2A). The difference in SFPS score significantly differed between the EXP and CON groups (Figure 2B).

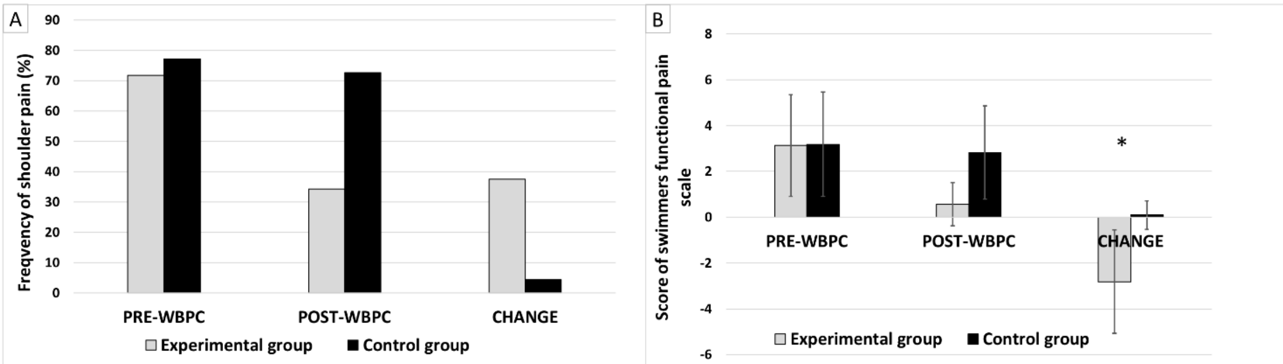

Figure 2. Changes in frequency (**A**) and score (**B**) of shoulder pain among swimmers. PRE-WBPC: before the whole-body correction program, POST-WBPC: after the whole-body correction program. The Cohen's d value of SFPS difference score was d = 3.292. * Significant difference ($p < 0.05$) between experimental and control group.

5.3. Results of Posture Analysis

In the post-WBPC period, there were significant differences in change of numerous posture variables (change in ATK, CVA, SF, TAA, TLA) between EXP and CON. All mentioned posture parameter improved higher in EXP (Figure 3).

5.4. Correlation between Posture Analysis and Swimmers Functional Pain Scale (SFPS)

Significant correlations were found between the change in PostureScreen parameters and the change in SFPS score (Table 3).

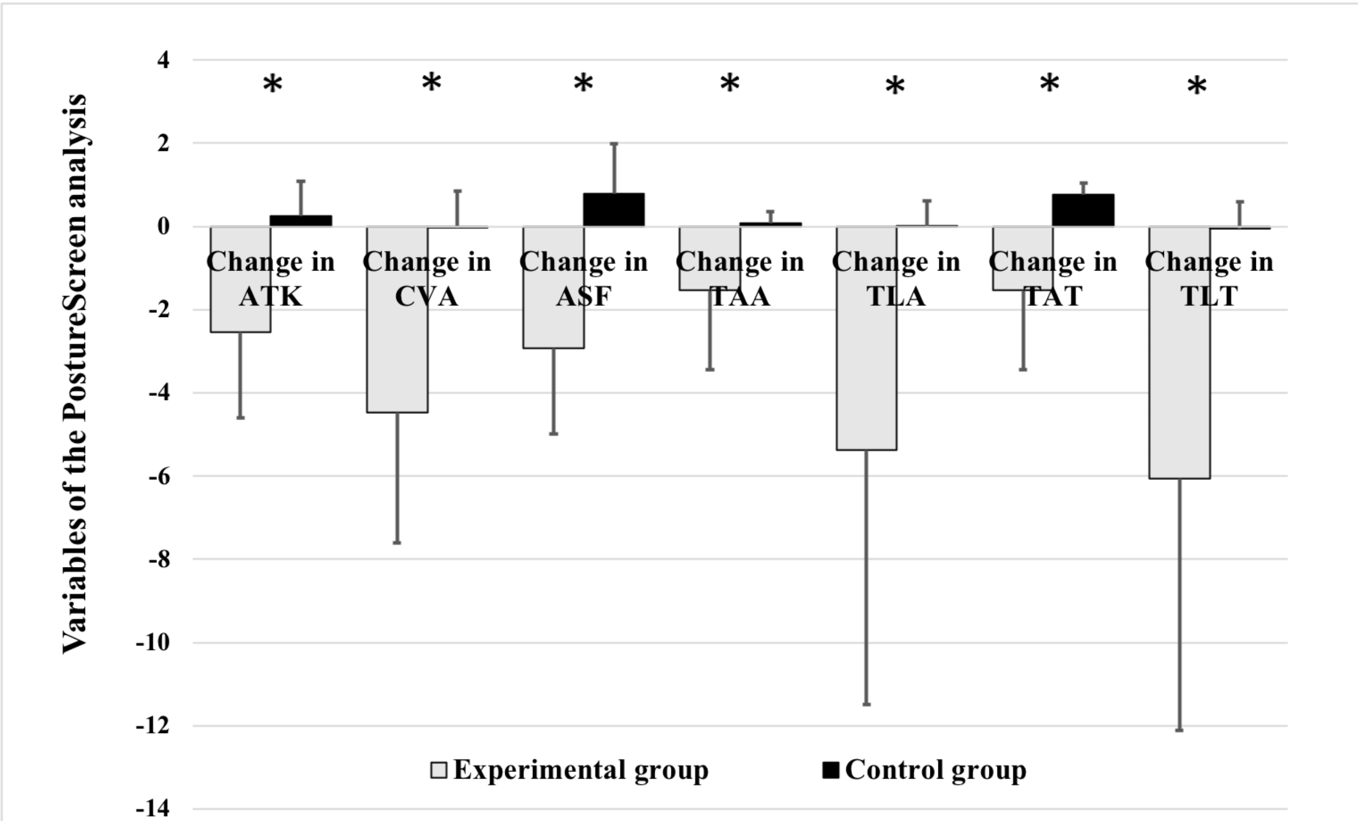

Figure 3. Changes in postural parameters among swimmers. Abbreviations: ATK: angulation of thoracal kyphosis, CVA: cervicovertebral angulation, ASF: angulation of skull flexion, TAA: total anterior angulation, TLA: total lateral angulation, TAT: total anterior translation, and TLT: total lateral translation. * Significant difference ($p < 0.05$) between experimental and control group.

Table 3. Pearson correlation between change in posture parameters and the change in SFPS score.

	Change in ATK	Change in CVA	Change of ASF	Change of TAA	Change of TLA	Change of TAT	Chang of TLT
Change of SFPS score	r = 0.438	r = 0.448	r = 0.498	r = 0.189	r = 0.230	r = 0.415	r = 0.280
p value	$p < 0.001$ **	$p < 0.000$ **	$p < 0.001$ **	$p = 0.174$	$p = 0.098$	$p = 0.002$ *	$p = 0.042$ *

Abbreviations: SFPS: swimmers functional pain scale, ATK: thoracal kyphosis, CVA: cervicovertebral angle, ASF: angulation of skull flexion, TAA: total anterior angulation, TLA: total lateral angulation, TAT: total anterior translation, TLT: total lateral translation, * Significant ($p < 0.05$) correlation between the two variables, ** Significant ($p < 0.001$) correlation between the two variables.

6. Discussion

The aim of our study was to investigate the effects of 24 weeks of a WBPC program on changes in whole-body posture in youth swimmers. A further aim of our study was to look for the correlation between variables of the posture analysis and shoulder function-related pain.

The main results of the study were as follows: the experimental group exhibited significant improvements in all postural parameters measured by PostureScreen, including (ATK, CVA, ASF, TAA, TLA, TAT, and TLT). Conversely, no significant changes were observed in the control group. Prior to the implementation of the exercise program, a high prevalence of habitual postural inadequacy was noted. However, after the completion of the program, a significant improvement in postural alignment was observed. These findings are consistent with previous studies that primarily focused on analyzing posture in the shoulder girdle and head region. Specifically, studies by Kluemper (2006) [16] and Lynch (2010) [17] reported significant improvements in shoulder alignment, while Lynch (2010) [17] also observed improved head girdle protraction following a 6–8 week intervention training period.

The experimental training group exhibited a reduction in both the intensity and frequency of pain, specifically in the anterior region of the shoulder. Conversely, the control subjects did not experience any positive changes in these variables following the training program. Prior to the intervention, 70% of the swimmers in our study reported experiencing pain in the anterior shoulder region, and this prevalence was consistent across both groups. These findings align with previous research, which has reported a wide range in the prevalence of shoulder pain among swimmers, ranging from 35% to 91%. Several publications [4–6,10–12,14,15] have indicated that shoulder pain in swimmers is a complex condition with multiple contributing factors, although the primary cause is believed to be the repetitive overhead motion involved in swimming [9] . When considering factors that contribute to the development of shoulder pain in adolescent competitive swimmers, it is crucial to examine their habitual posture. Postural dysfunction abnormality is an intrinsic factor that can potentially lead to the onset of shoulder pain. During adolescence, maintaining good posture becomes even more important due to the rapid growth changes that occur. Poor posture during this period increases the risk of injury [24]. Additionally, functional deficiencies have been identified as playing a significant role in the high prevalence of shoulder pain [19] . In our study, the participants had not previously engaged in any dryland training program, which may explain the high occurrence of shoulder pain prior to the intervention. However, after implementing our program, we observed a decrease in the frequency of pain among the group that received the intervention, while the presence of pain remained unchanged in the control group.

Numerous scientific studies [16,17,29] have provided evidence supporting the positive effects of intervention trainings on the improvement of shoulder and/or head position, as well as the enhancement of shoulder muscle strength. These improvements have been shown to result in a decrease in the occurrence of shoulder pain. Notably, it is important to highlight that only the experimental swimmers exhibited a statistically significant ($p < 0.05$) reduction in the swimmer's functional pain scale (SFPS) value following the intervention. Specifically, their SFPS score decreased from 3.1 to 1. While previous research [17] has investigated the prevalence of shoulder pain among swimmers, our study uniquely observed a significant change in the SFPS score solely within the experimental swimmer group. This discrepancy may be attributed to the relatively short duration of the training program, which potentially explains the lack of substantial differences in shoulder pain reported in the majority of previous studies.

The observed decrease in pain demonstrated a significant association with changes in the various variables of PostureScreen. While the majority of the relationships showed statistical significance between alterations in SFPS and modifications in posture parameters, the correlations were moderately positive. The findings of this investigation suggest that achieving more optimal biomechanical conditions may indirectly lower the risk of developing swimmer's shoulder as a preventive measure. Numerous previous studies [2,3,16,17,24,27–31] have emphasized the potential benefits of dry-land training in restoring normal shoulder posture and muscle balance in competitive swimmers. However, limited information is available regarding the extent to which pain is reduced, if at all, and most of these studies have focused on specific treatment of shoulder muscles. Previous research conducted by Bak (2010) [24], Dorssen (2020) [3], Hibberd (2012) [29], Kluemper (2006) [16], Lynch (2010) [17], Nichols (2015) [30], Ruivo (2016) [31], Sousa (2019) [32], and Tessaro (2017) [2] has indicated that incorporating core training, shoulder strengthening, and stretching exercises into preventive interventions for swimmers may lead to improvements in postural alignment and a reduction in shoulder pain. These studies have emphasized the significance of core strengthening in preventing shoulder pain and promoting optimal biomechanical function of the upper limb by establishing proximal stability. Building upon these findings, our study suggests that implementing a sport-specific training program for young swimmers could have a substantial impact on their posture development and help alleviate shoulder pain. It is worth noting that, prior to our research, there was no conclusive evidence supporting the effectiveness of comprehensive postural correction training in reducing shoulder pain. Furthermore, the current investigation has established a correlation between the severity of anterior shoulder pain and alterations in postural parameters over a period of 24 weeks of preventative training in young individuals engaged in swimming. Moreover, our results underscore the significance of implementing enduring land-based training regimens to effectively tackle and preempt sport-related issues that are unique to swimmers. It is imperative to acknowledge that brief interventions are inadequate for achieving the desired optimal results.

The analysis and continuous monitoring of an athlete's posture, facilitated by the PostureScreen mobile app, offers the advantage of identifying postural changes as pain arises and enables timely intervention [26]. The assessment of swimmers' posture through the use of a mobile application represents a pioneering and practical approach that can accurately detect deviations from optimal posture using objective data. PostureScreen, an evidence-based software for postural analysis, is applicable in both clinical settings [40] and sports research [25,33,41] . In our study, the implementation of PostureScreen proved to be a reliable method for objectively identifying alterations in body posture and monitoring changes in young swimmers' postural alignment.

7. Strengths and Limitations

The strength of our study to assess high number of subjects and the efficacy of our novel whole-body posture correction training program on shoulder pain in a controlled trial. One of the limitations of our study was our focus on only one influencing factor (poor body posture) in the development of shoulder pain in youth athletes. Furthermore, we had different age groups but none of the participants had completed any additional training before, so the exercises were completely new and unfamiliar stimuli for all of them.

8. Conclusions

In the present study, we provided evidence that a 24-week-long whole-body posture correction program reduces anterior shoulder pain, and that magnitude of pain reduction is associated with changes in postural variables. Our study revealed the importance of proper body posture as a biomechanically optimal prerequisite for swimming performance among youth athletes.

We suggest that the continuous monitoring of posture using an on-site mobile application among young swimmers and the use of preventive training may help to prevent the development of injuries and complaints (such as anterior shoulder pain) at a young age.

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Informed Consent Statement: Informed consent was obtained from all subjects involved in the study. Written informed consent has been obtained from the patient(s) to publish this paper.

Data Availability Statement: The data presented in this study are openly available in FigShare at https://doi.org/10.6084/m9.figshare.24981567. URL (accessed on 23 January 2024).

Conflicts of Interest: Author K.G. is employed by the Pathology Innovation Incubator Lt. The remaining authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

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